

DETECTING EMERGING SINKHOLES WITH FWD TESTING

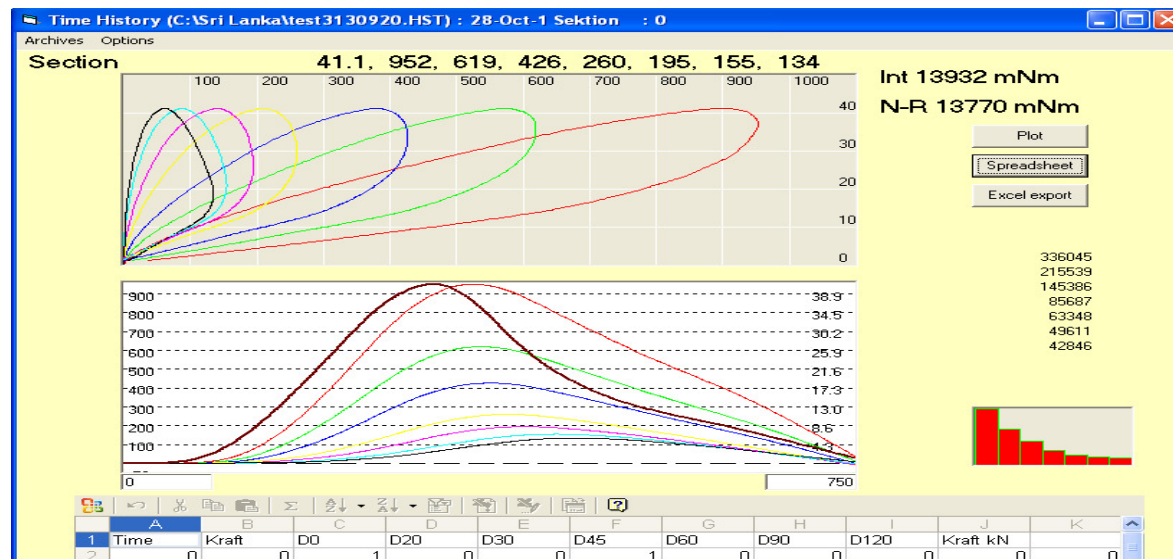


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Lund University
2014 FAA WORLDWIDE TECHNOLOG
TRANSFER CONFERENCE
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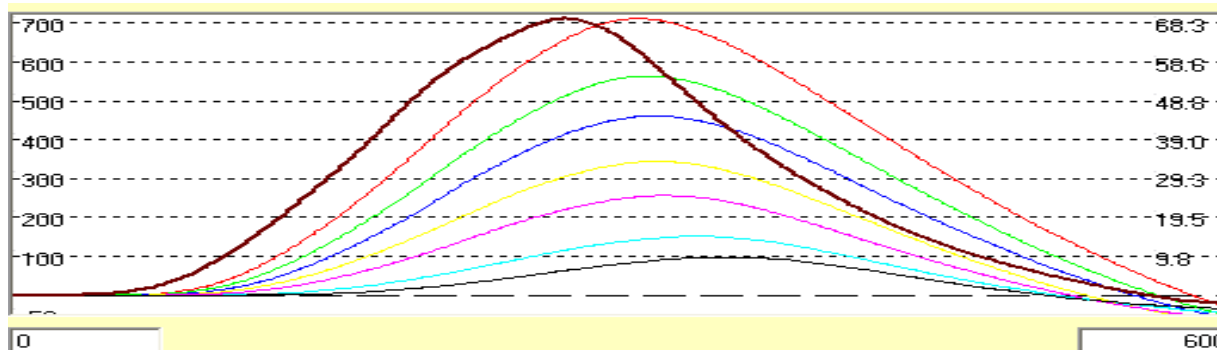
Objective

To find dynamic response characteristics for sinkholes!



Quick Course

Assessing Pavement Properties by Time History Analysis of Deflection



Background:

Rolling Deflectometer Tests

- During 1990:s a test of pavement dynamic response was carried out with a Road Deflection Tester.

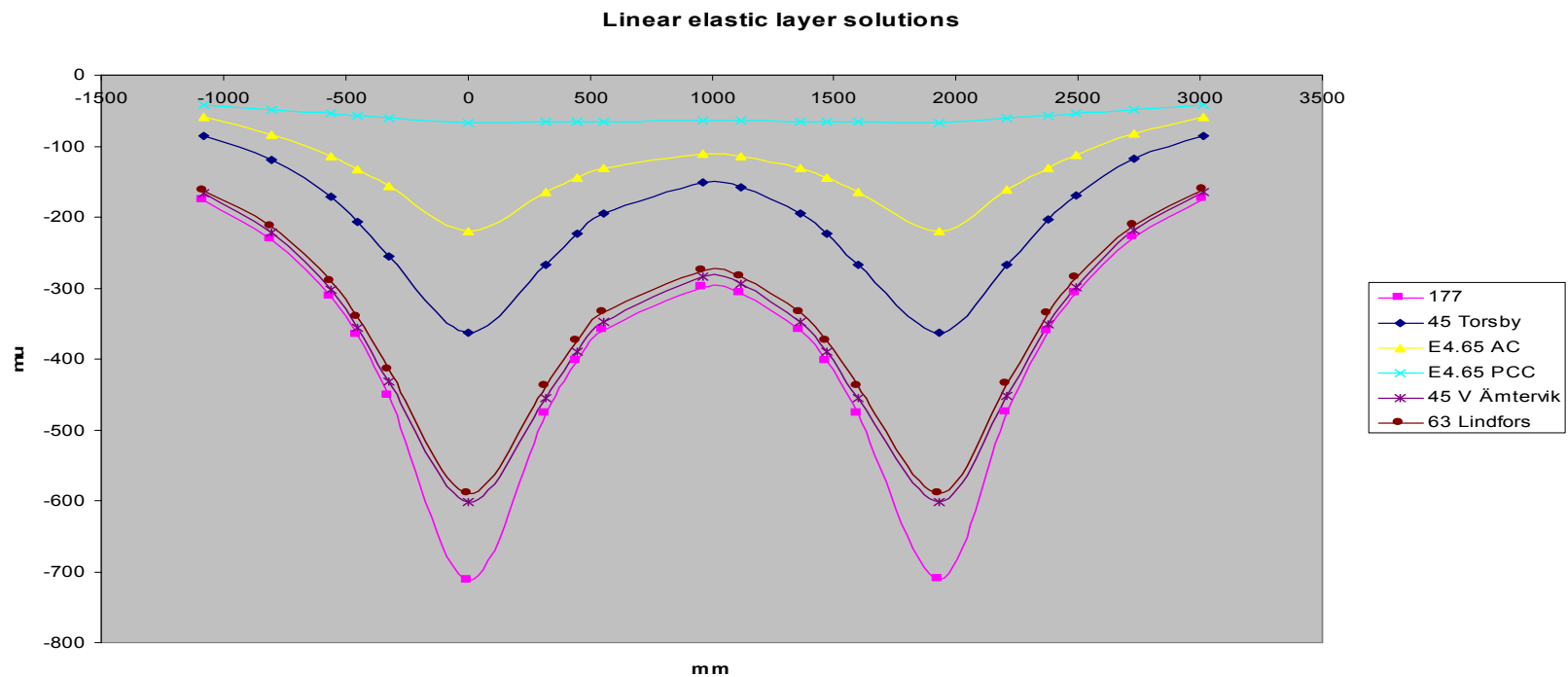


Rolling Deflectometer Tests

- The RDT was validated by Falling Weight Deflectometer Tests



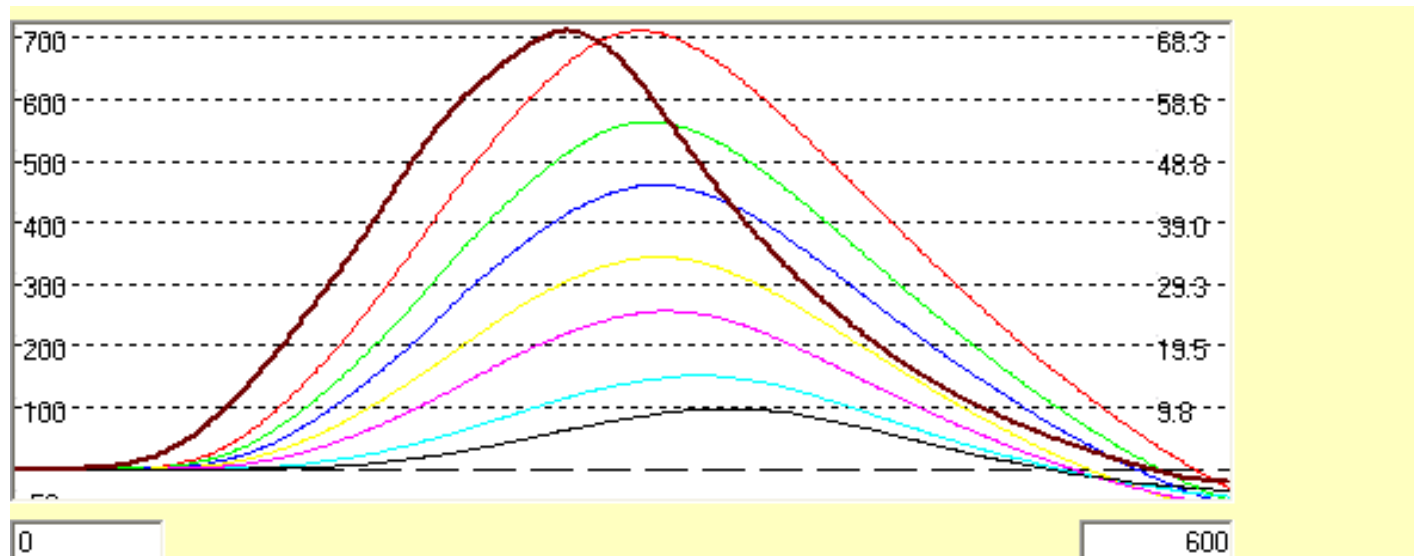
Various pavement and subgrade types. 130 Test Sections



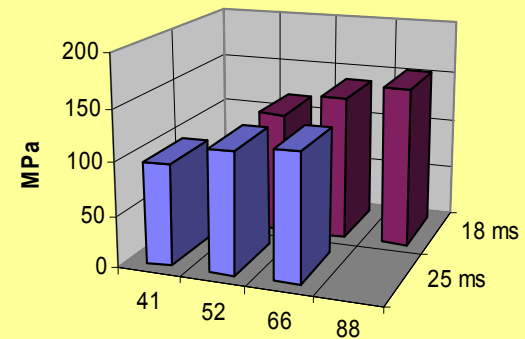
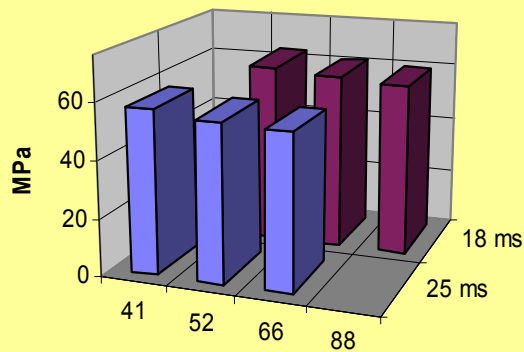
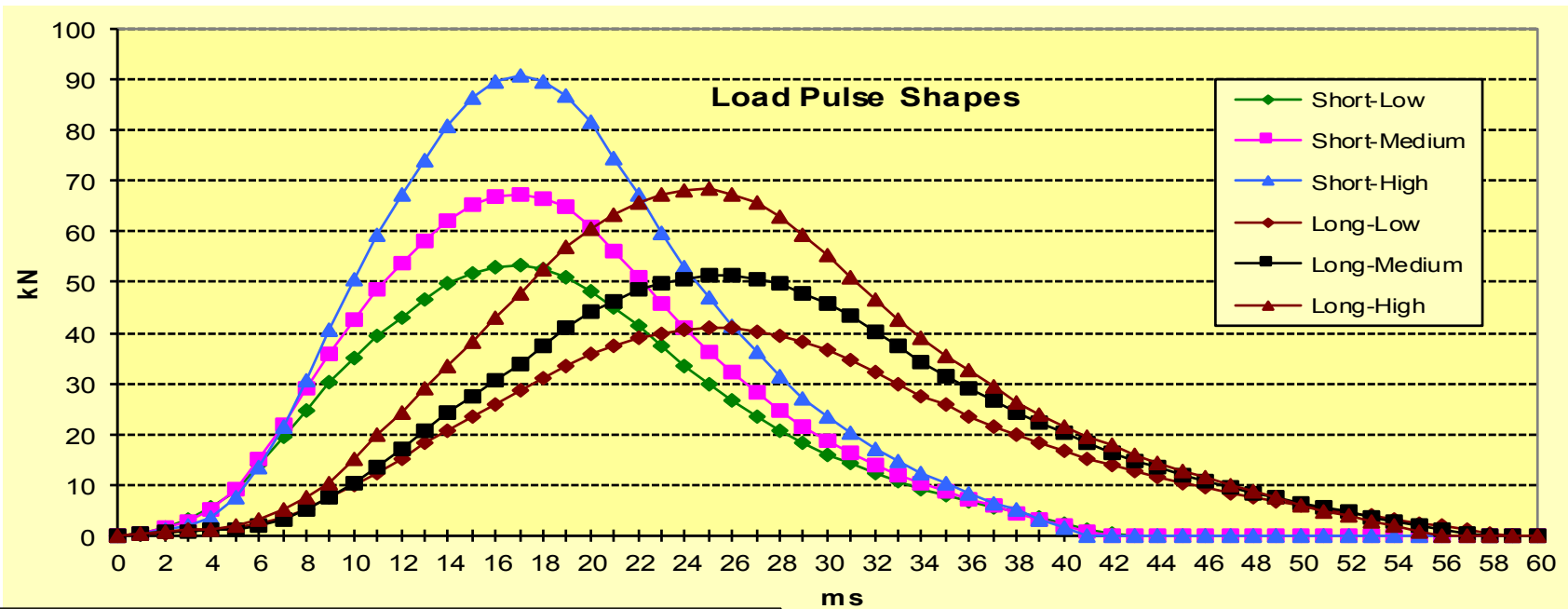
Transverse deflection profiles from truck load

First results

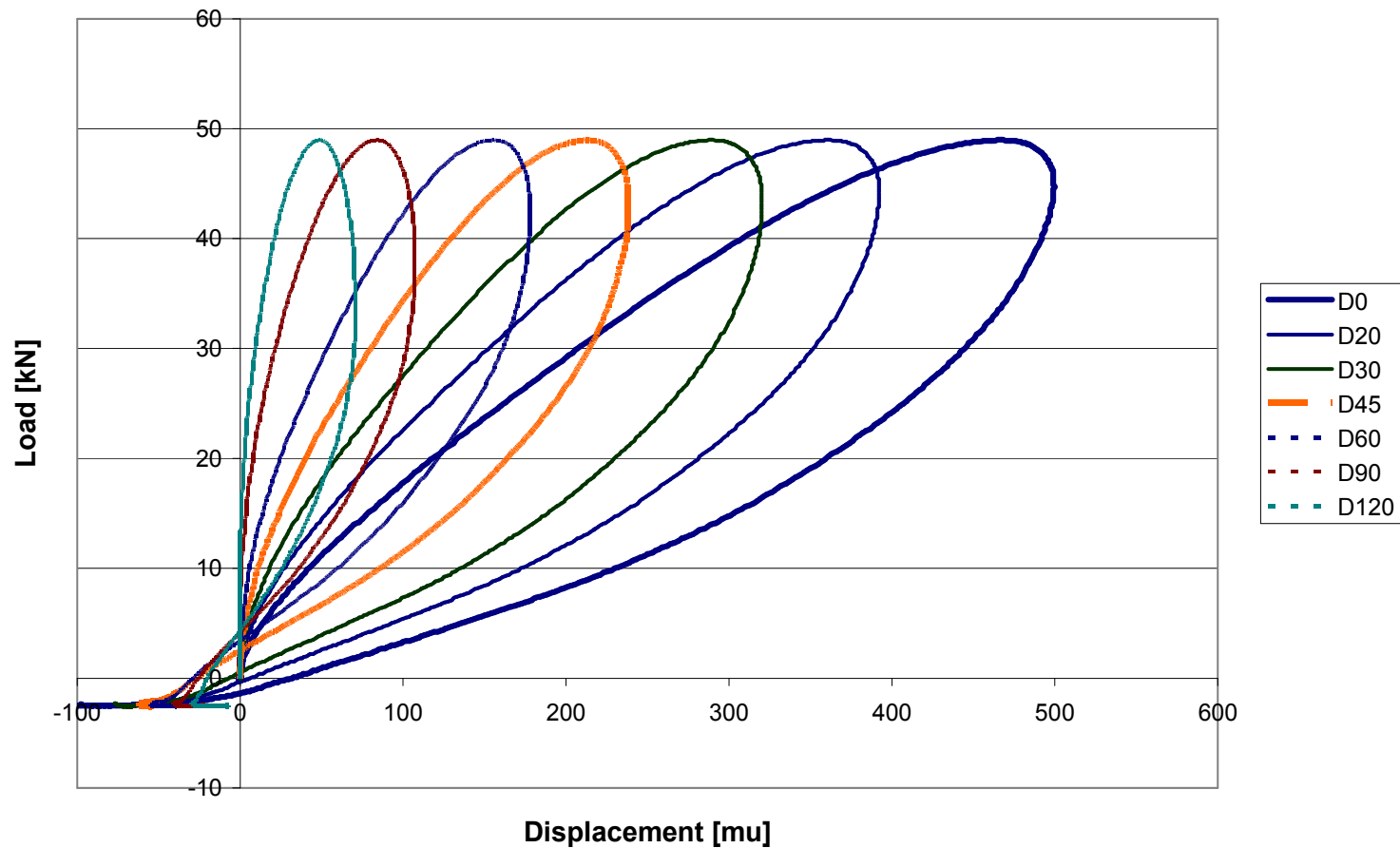
- Test verified significant difference between pavement types.



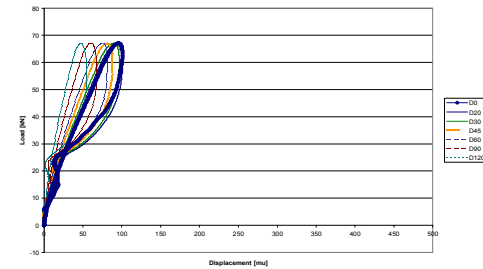
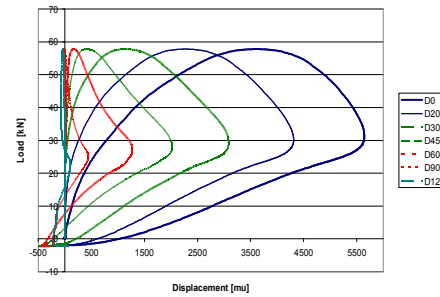
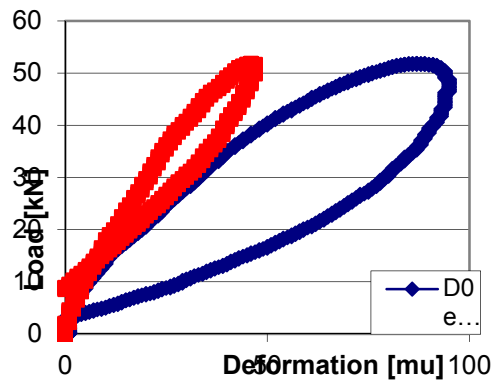
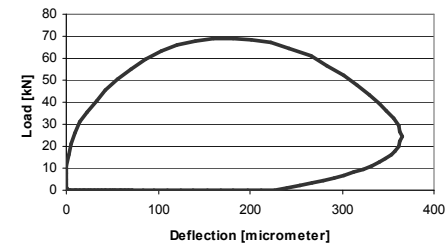
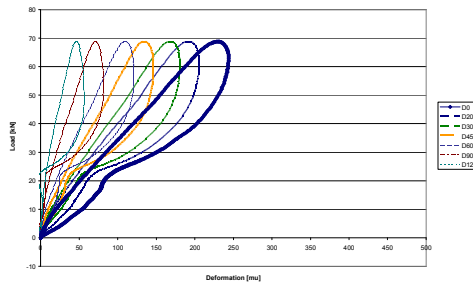
Load Mode and Magnitude Affect Properties



By plotting load vs. displacement
hysteresis curves are attained

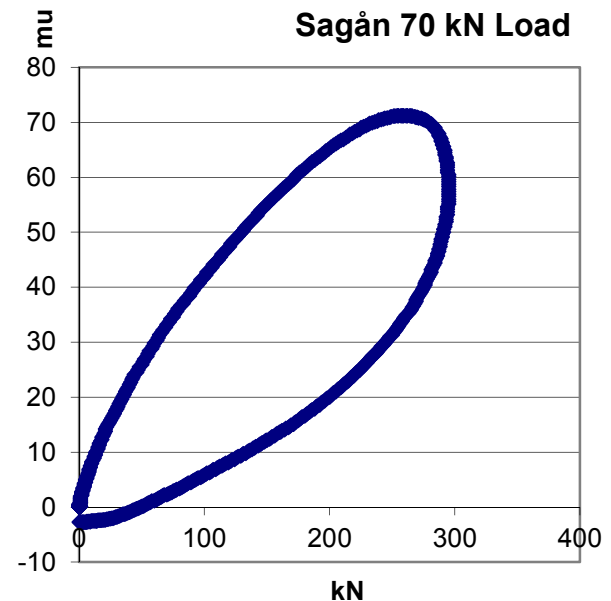


Area of curve corresponds to dissipated work

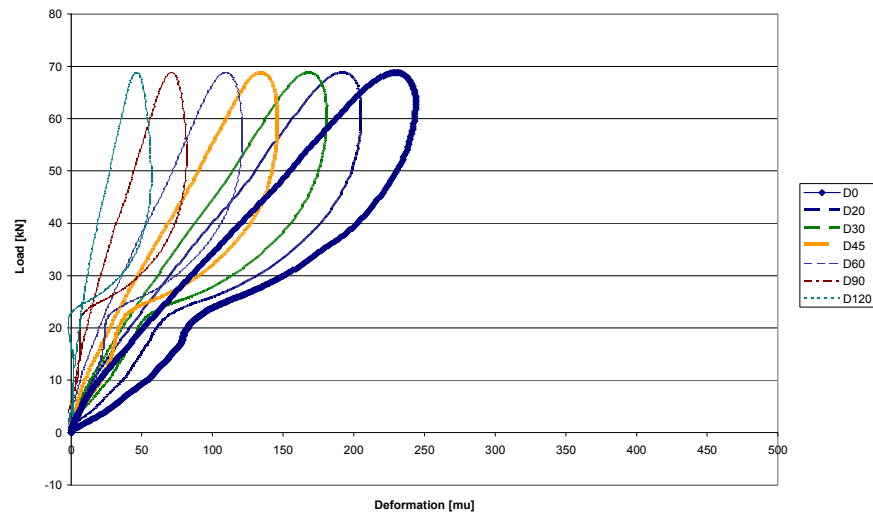


Note! The Load-Displacement Loops are not a direct measure of hysteresis, but they reflect:

- Visco-elastic properties
- Soil Damping
- Material moving
- Water moving
- Inertia

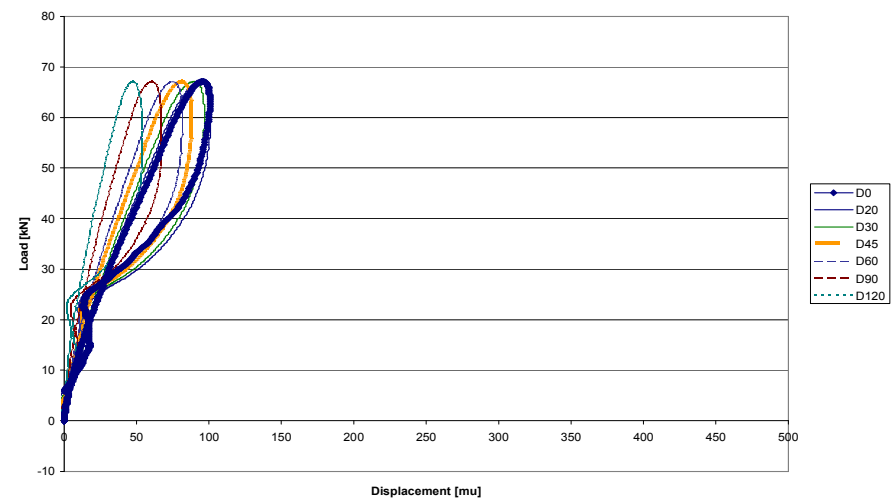


Calibration with actual truck fuel consumption tests in 2007



Flexible 4.2 Nm
@70kN

Rigid 1.04 Nm
@70 kN



Common Evaluation of Time Histories

- In-Field AC Master Curve Assessment
- Pavement Sustainability Assessment
 - Rolling Resistance
 - Jointed PCC Pavements
- Construction Control
 - Compaction
 - Saturated Soil Detection

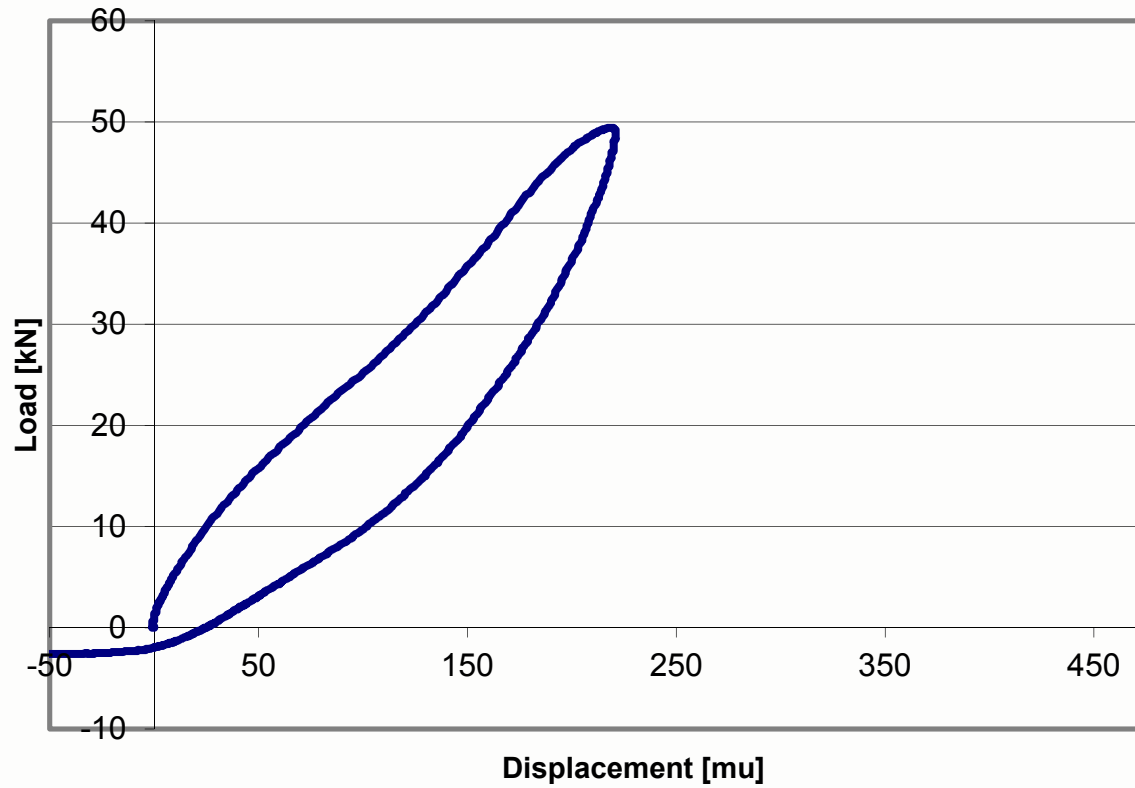
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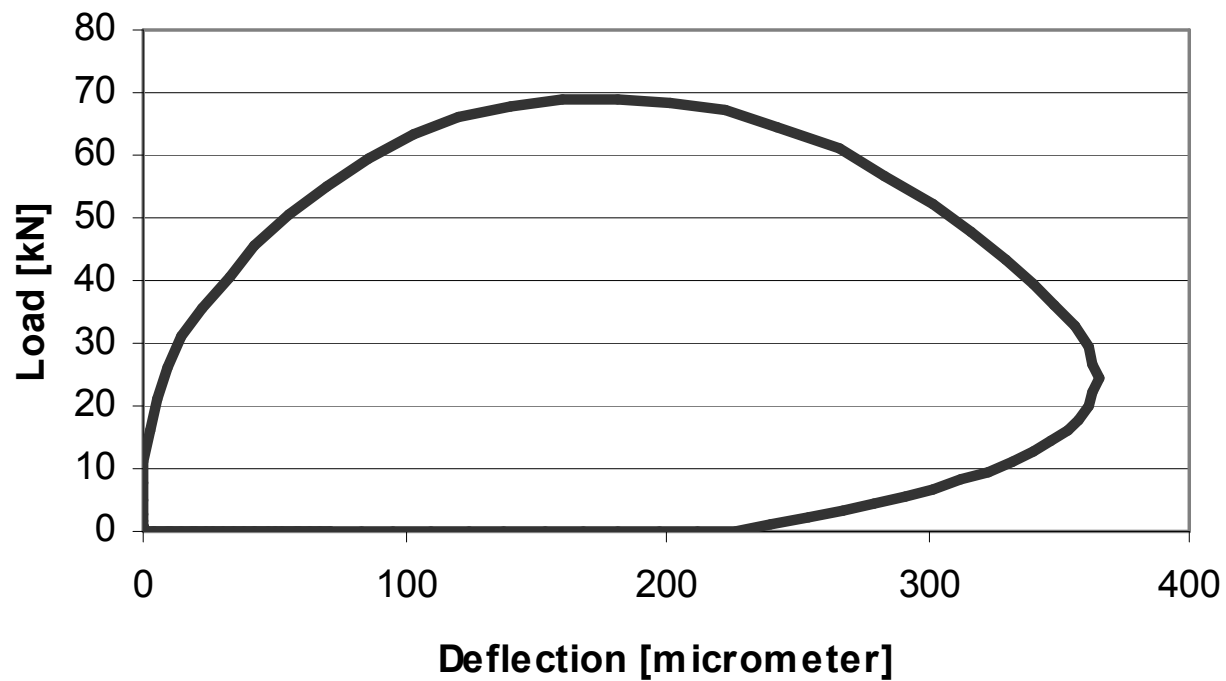
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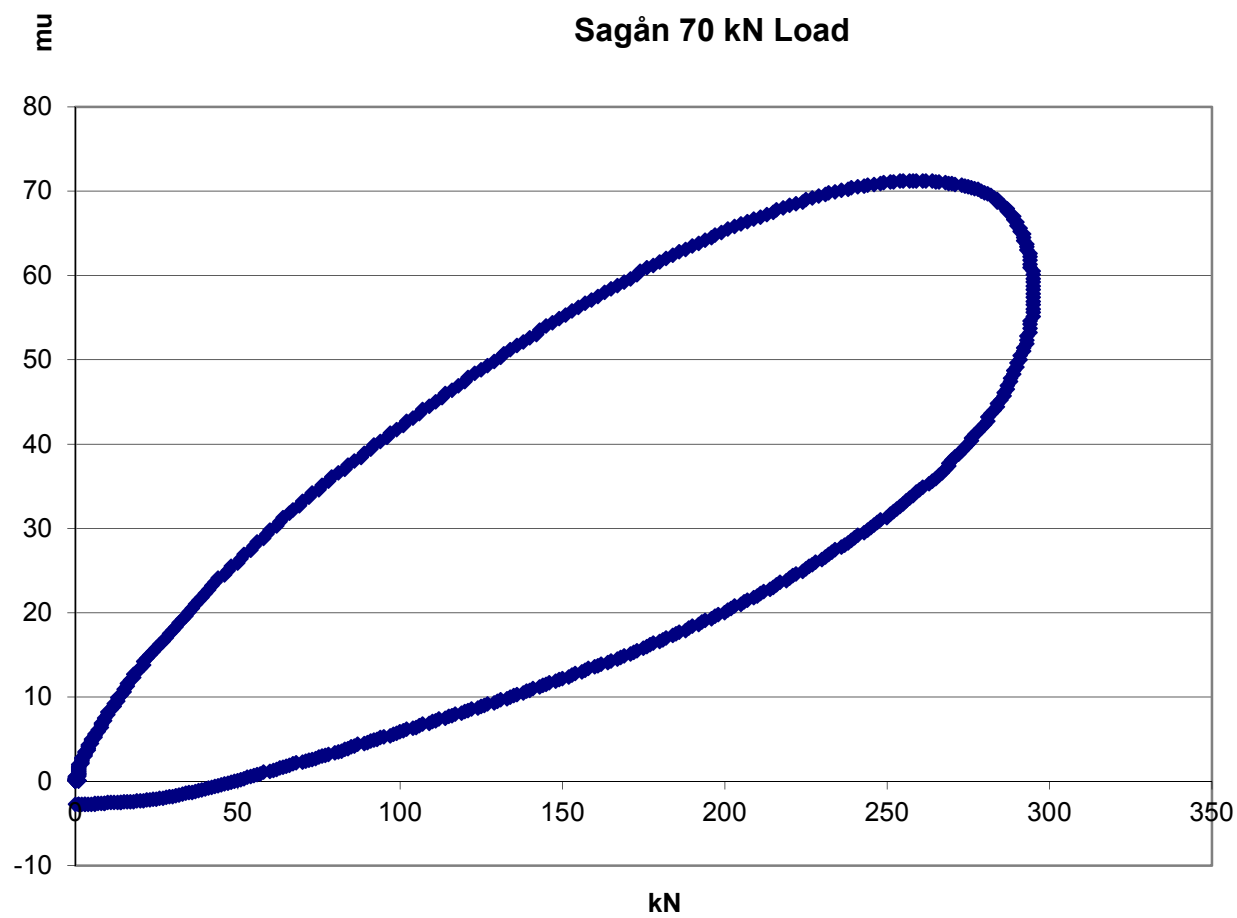
Asphalt Concrete on Stiff Subgrade



Example: 180 mm Thick Asphalt Concrete Load-Deflection Diagram at 40°C

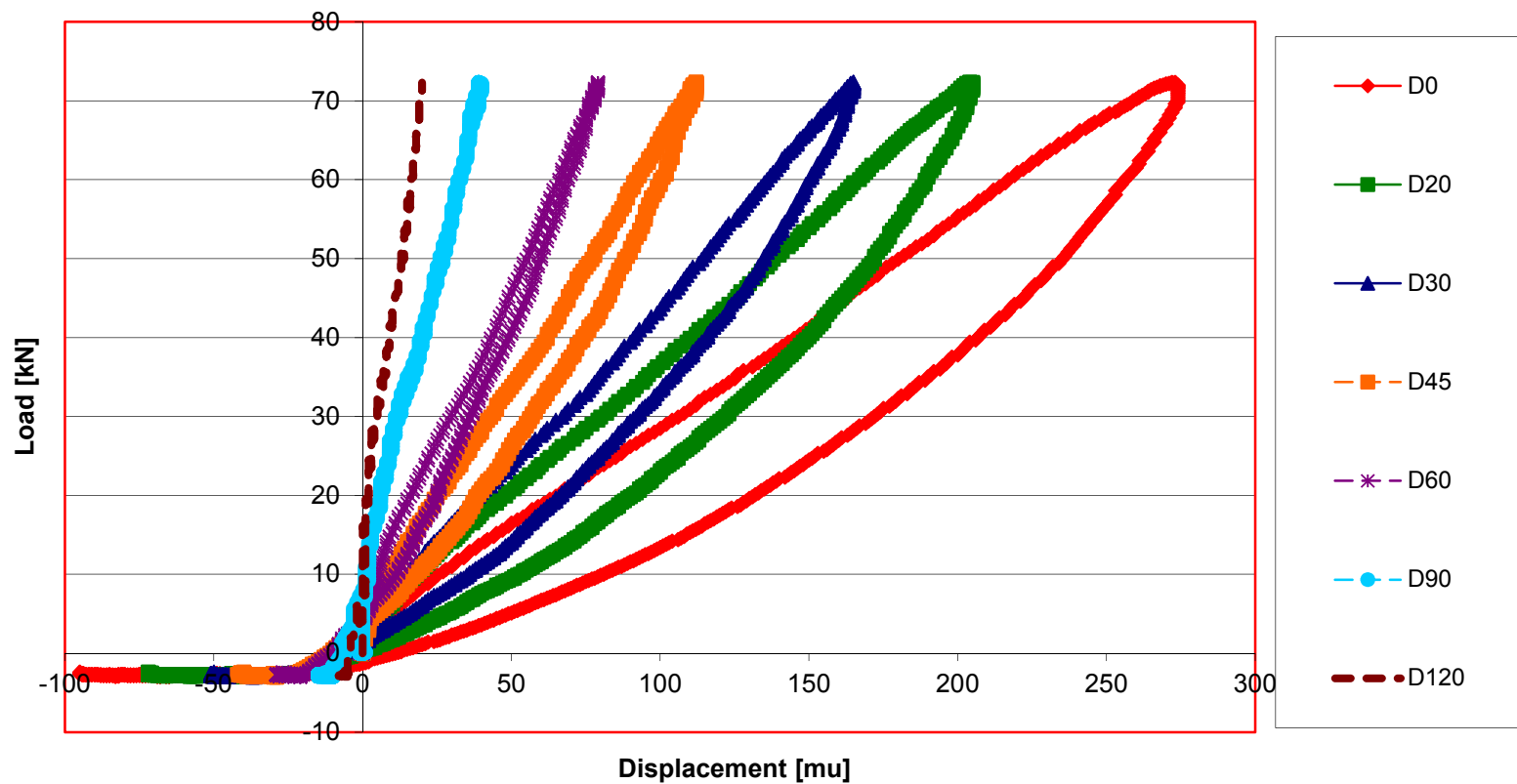


New 200 mm ACP @ 70 kN and
@ 10 degrees C



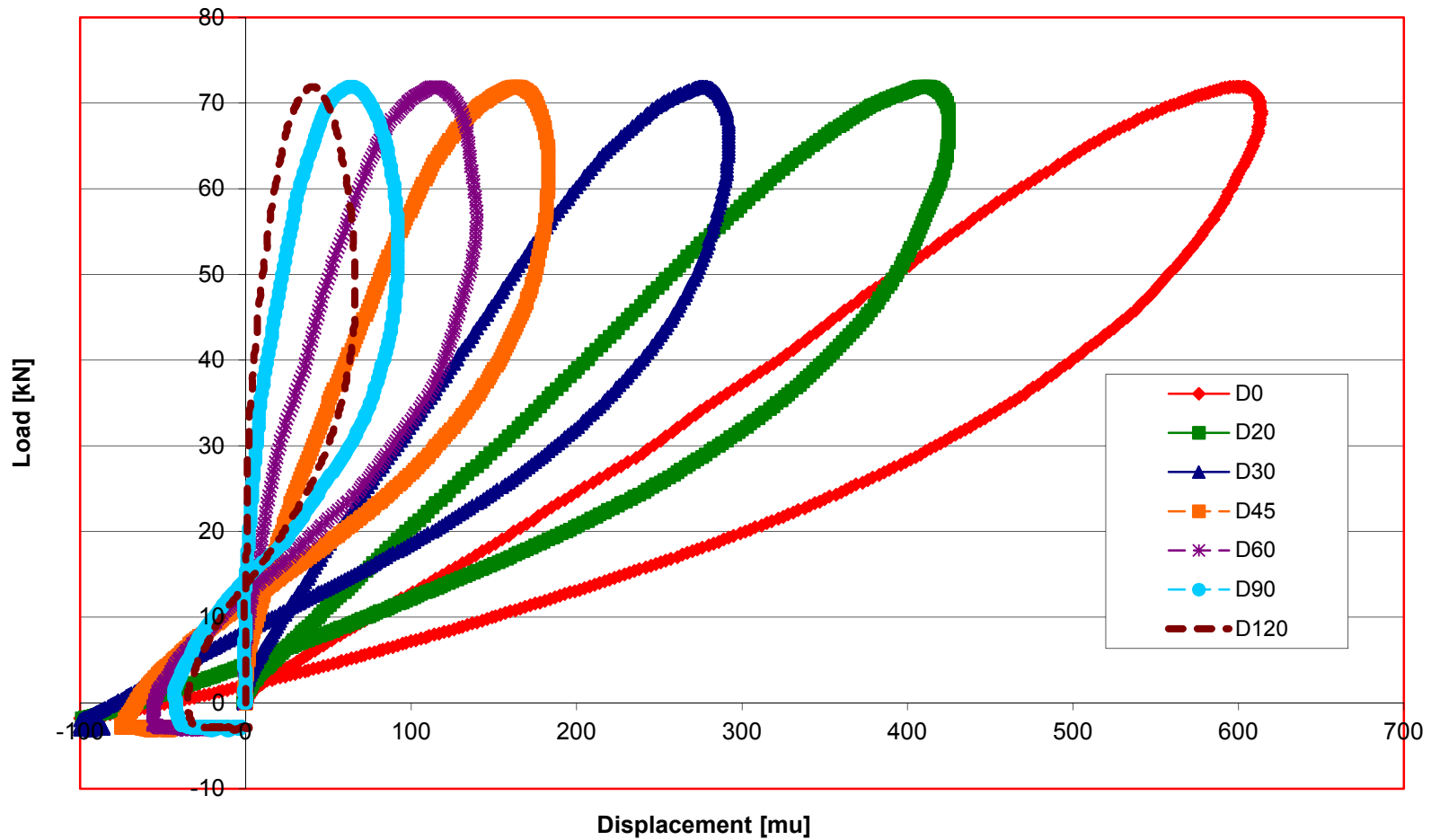
Intermediate 2-lane (new)

Hästbo Section: 2750 Drop: 10; Height: 4 Int 3863 mNm

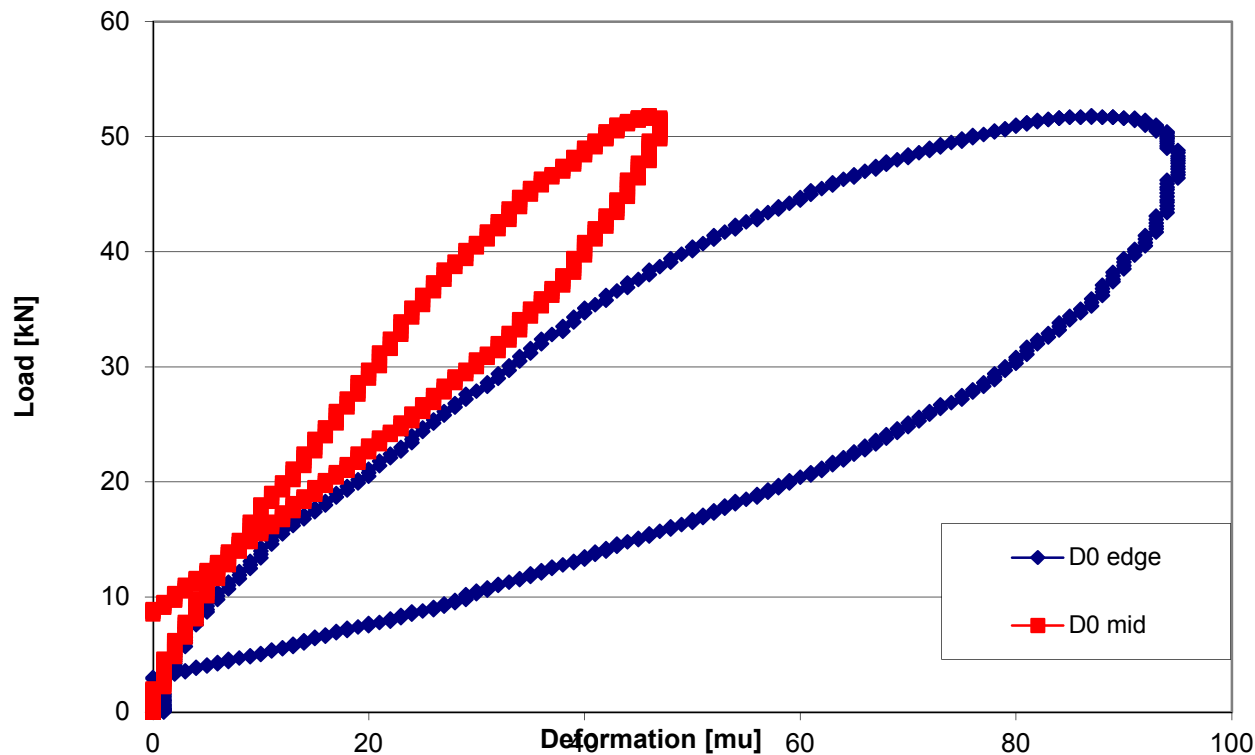


Low Volume Trunk Road

X512 Section: 265 Drop: 10; Height: 4 Int 9374 mNm



Effect of Curling Slabs

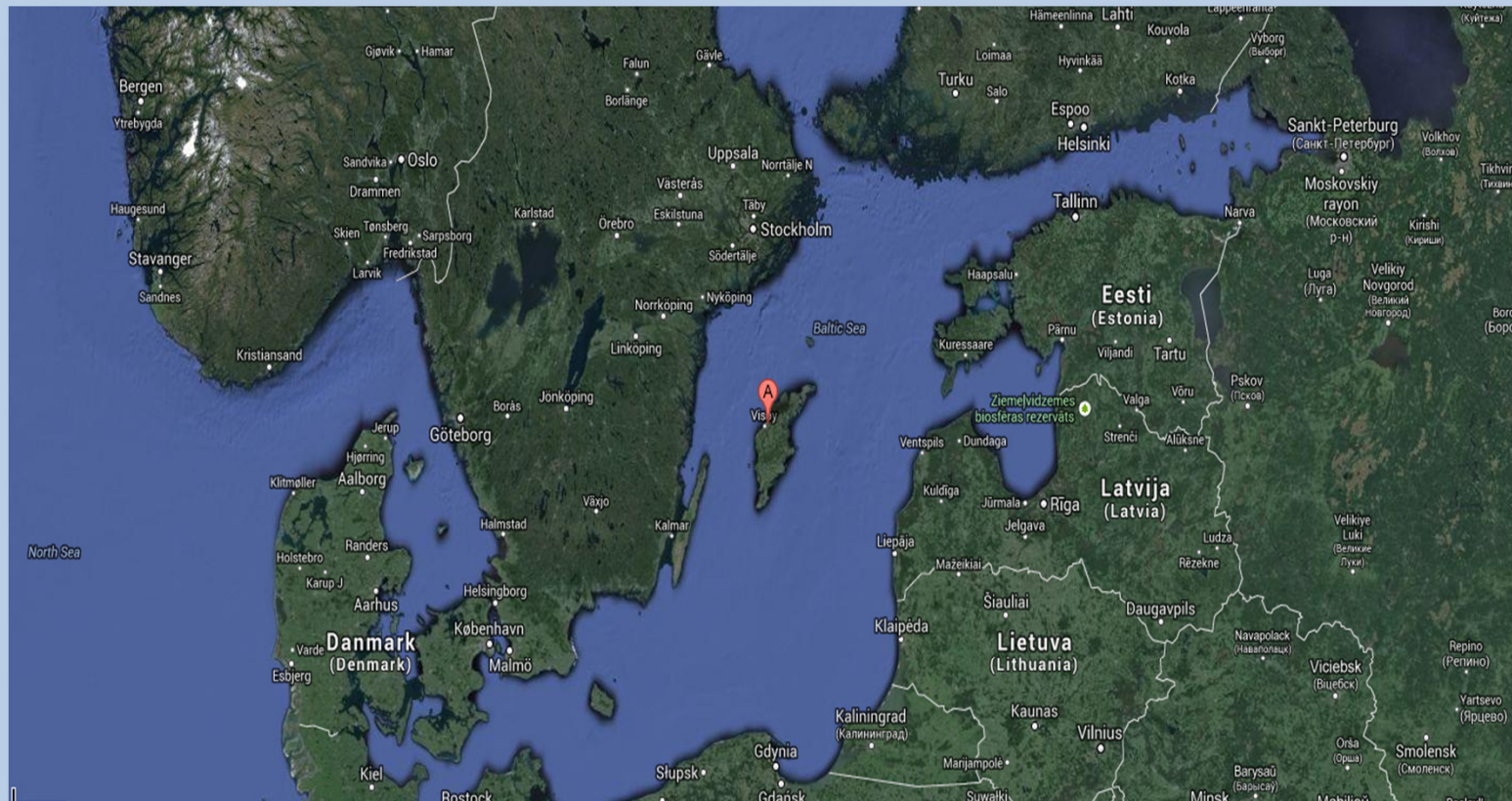


The edge effect was only apparent at the joint. → overall contribution estimated to about 10 % higher for the moving vehicle.

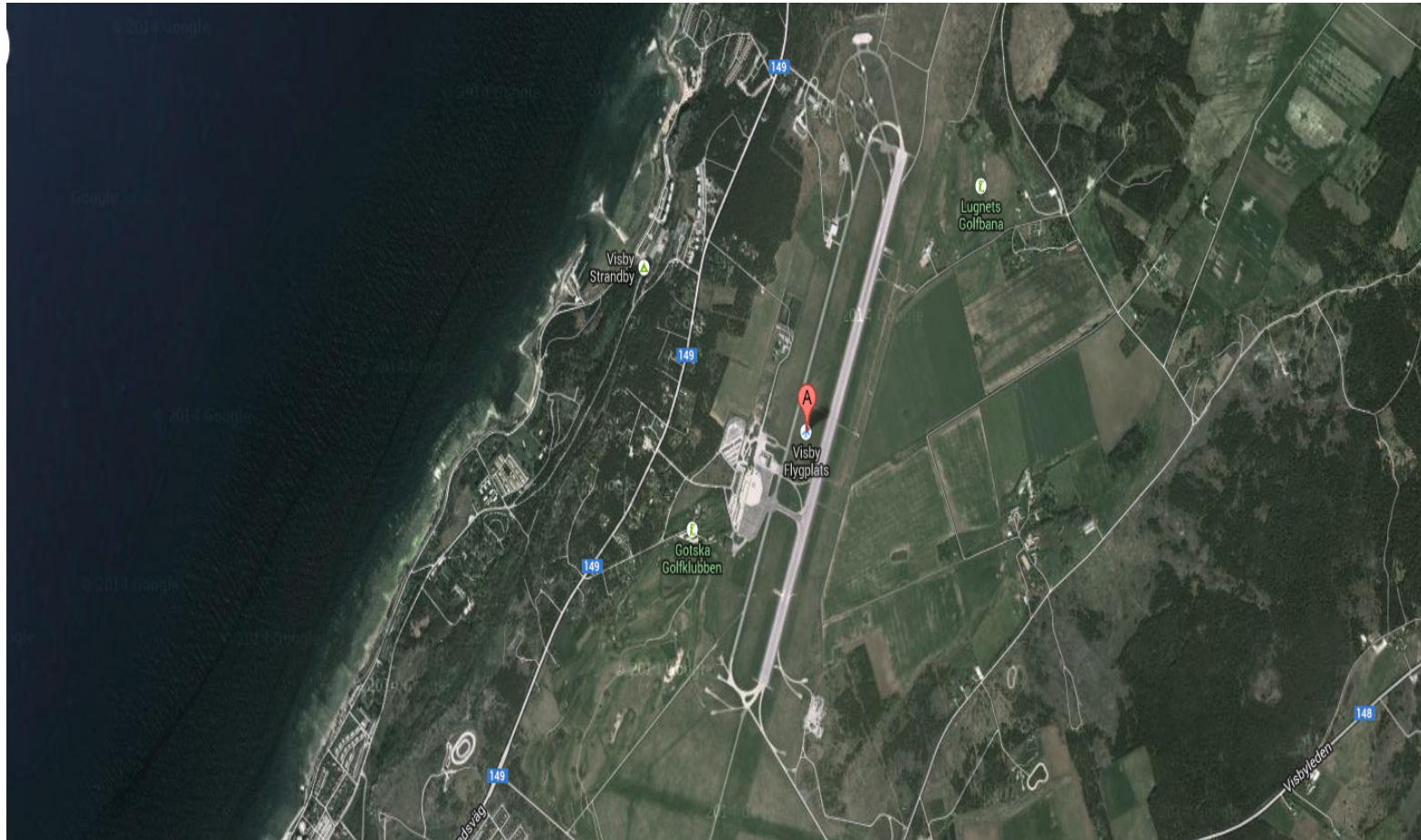
Relative Difference on dissipation for Various Pavement Types, Soft Soils

| | Flexible | Semi-Rigid | Jointed Rigid | Continuously Reinforced |
|-------------------------|----------|------------|---------------|-------------------------|
| Flexible | 1 | 2 | 2.3 | 2.6 |
| Semi-Rigid | .5 | 1 | 1.07 | 1.13 |
| Jointed Rigid | .43 | .93 | 1 | 1.07 |
| Continuously Reinforced | .38 | .88 | .93 | 1 |

Visby Airport, Gotland



Visby Airport, Gotland



Visby Airport, Gotland



Serves Island Population of 48 000.

Tourist traffic during Summer Months

Visby is a Medieval town on the Unesco World Heritage List!



Photos courtesy of Gotland Tourist Board

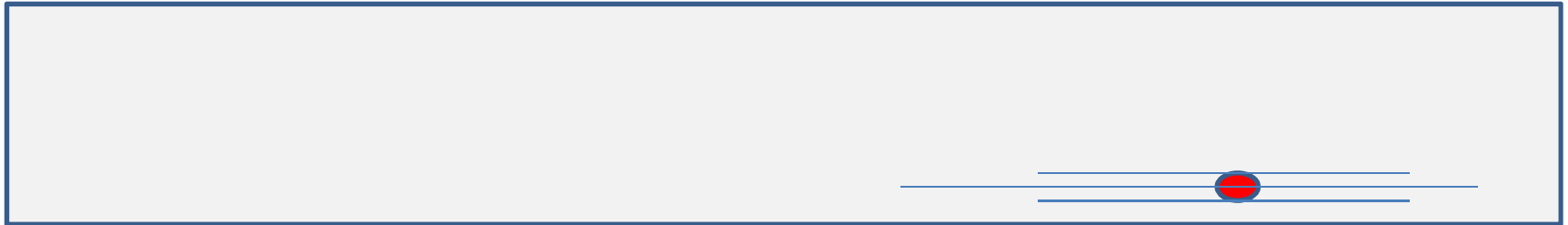
Surface Distress



Photo: courtesy of Swedavia

FWD Testing Layout

Three Lines along runway



Test sequence [kN]

| D r o p | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|------------------|----|----|----|----|----|----|----|----|----|
| L o a d | 25 | 25 | 40 | 50 | 70 | 25 | 40 | 50 | 70 |

Backcalculation

Evercalc 4.0 Linear-Elastic Program
Three and Four Layer Models

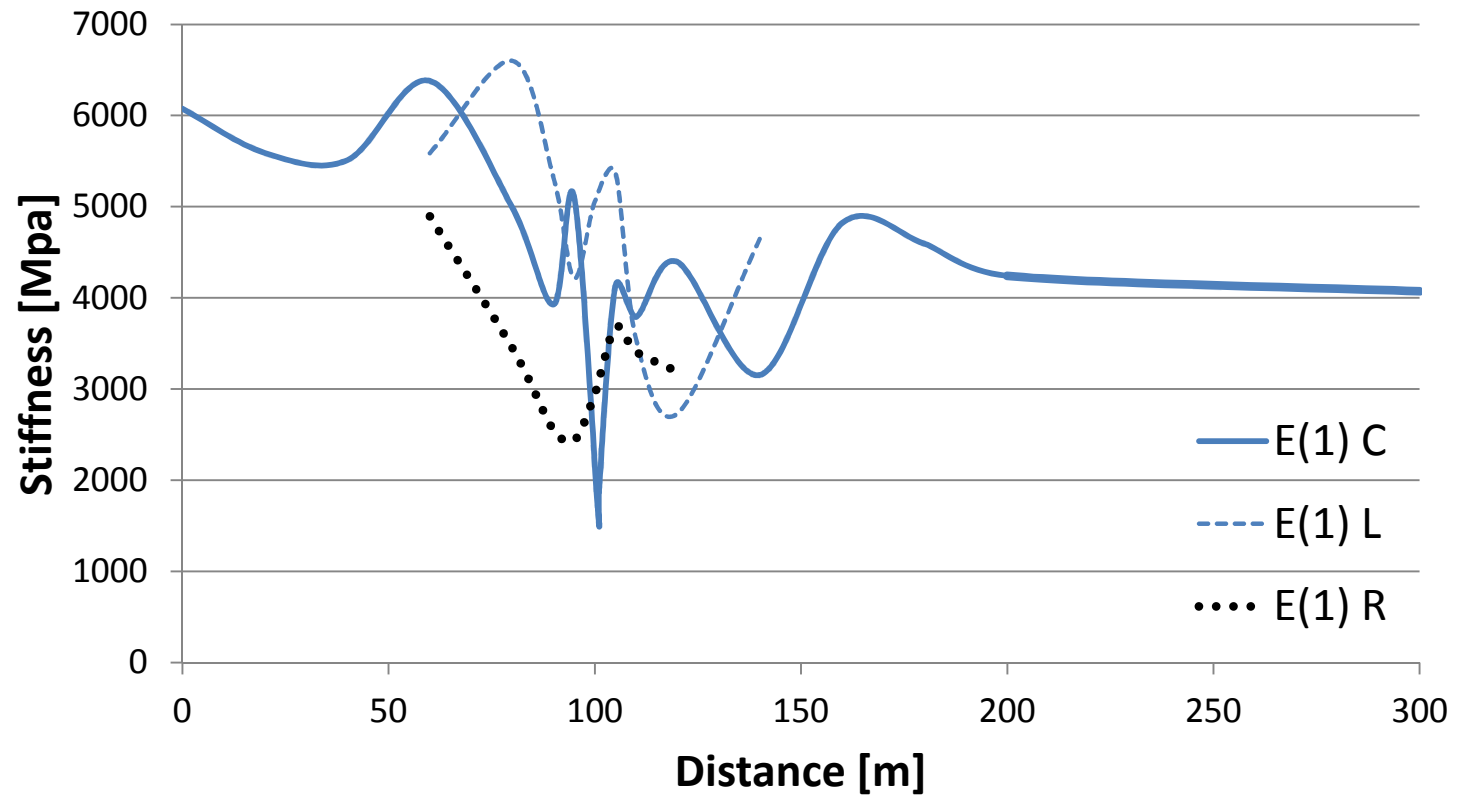
RMS per sensor

3L 1.5 to 5.0 %

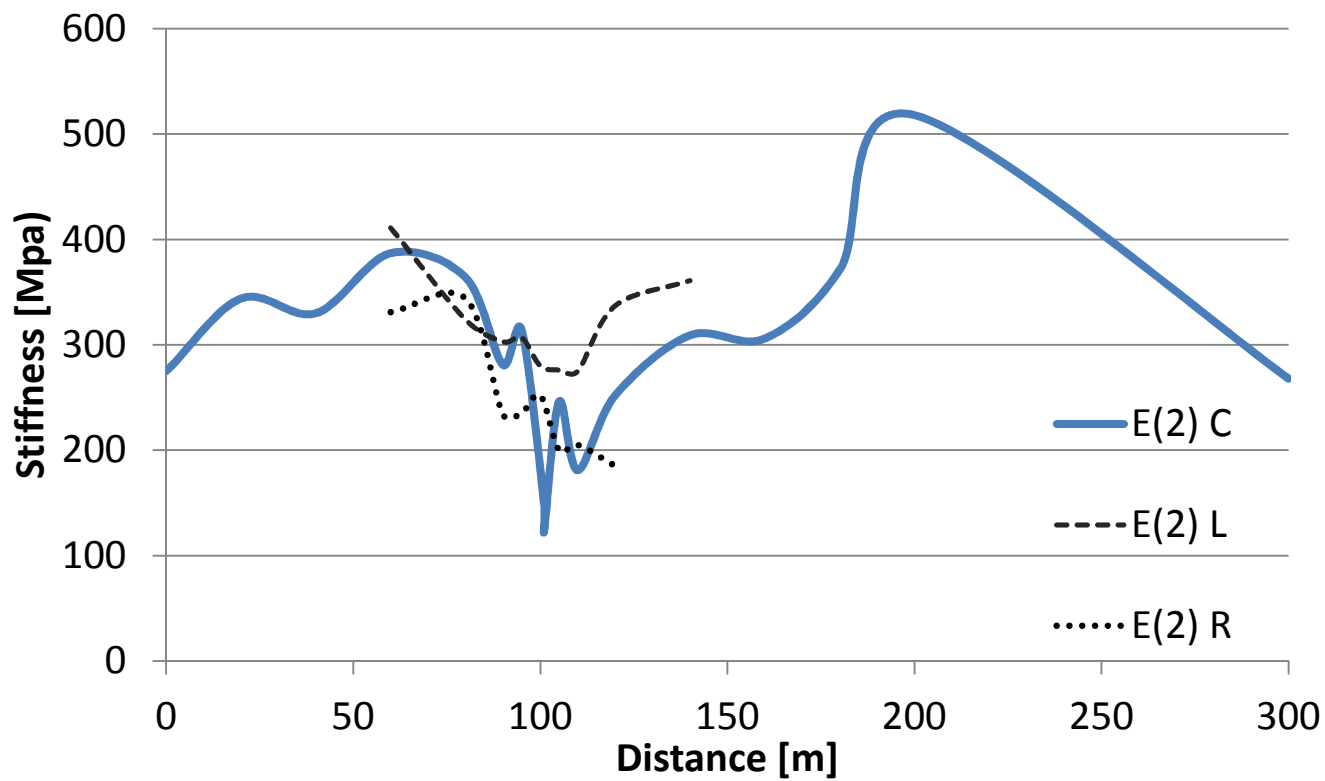
4L 0.8 to 3.5 %

(Acceptable for overlay design
Not acceptable for research).

AC Modulus @15C



Unbound Layers

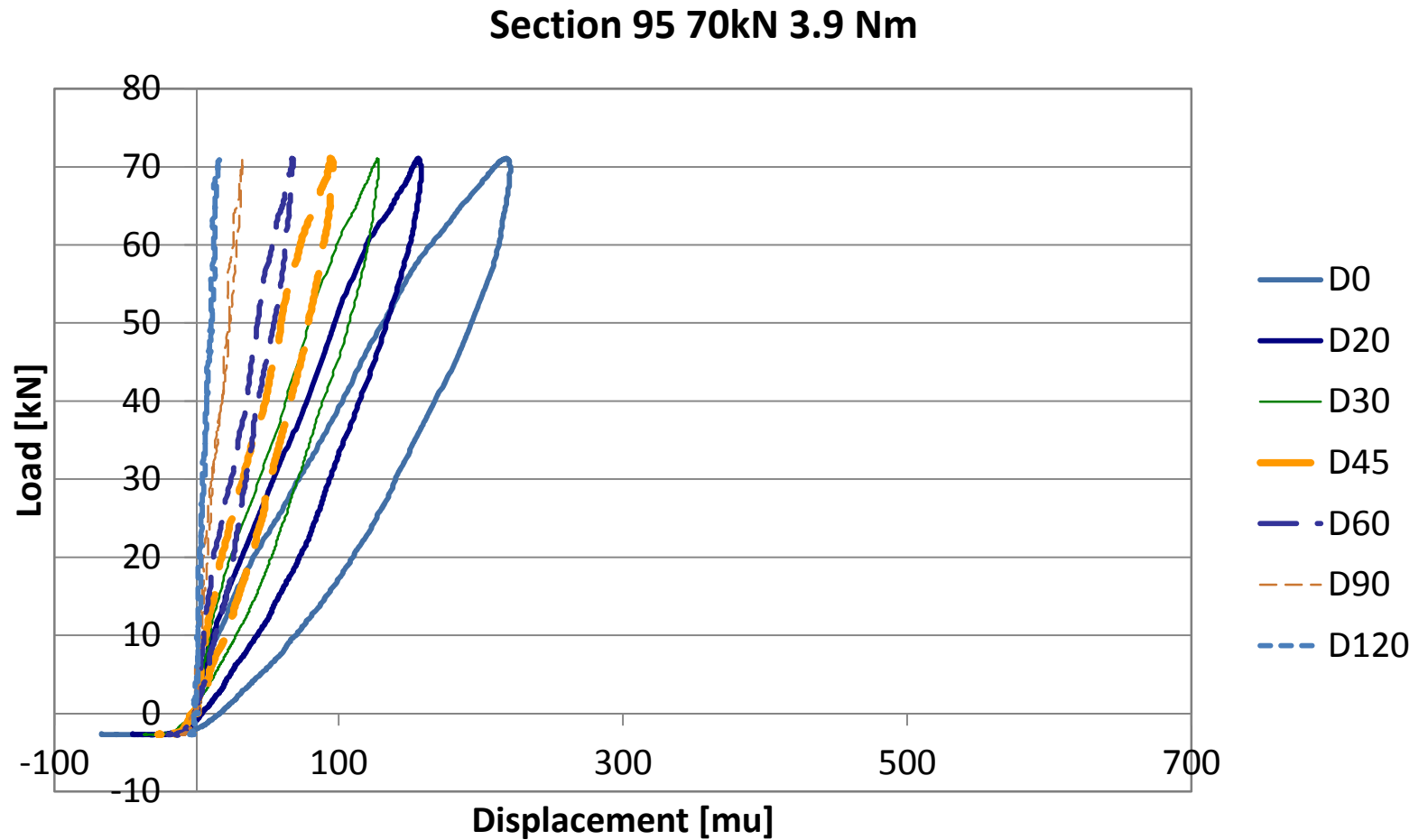


Elastic Solution

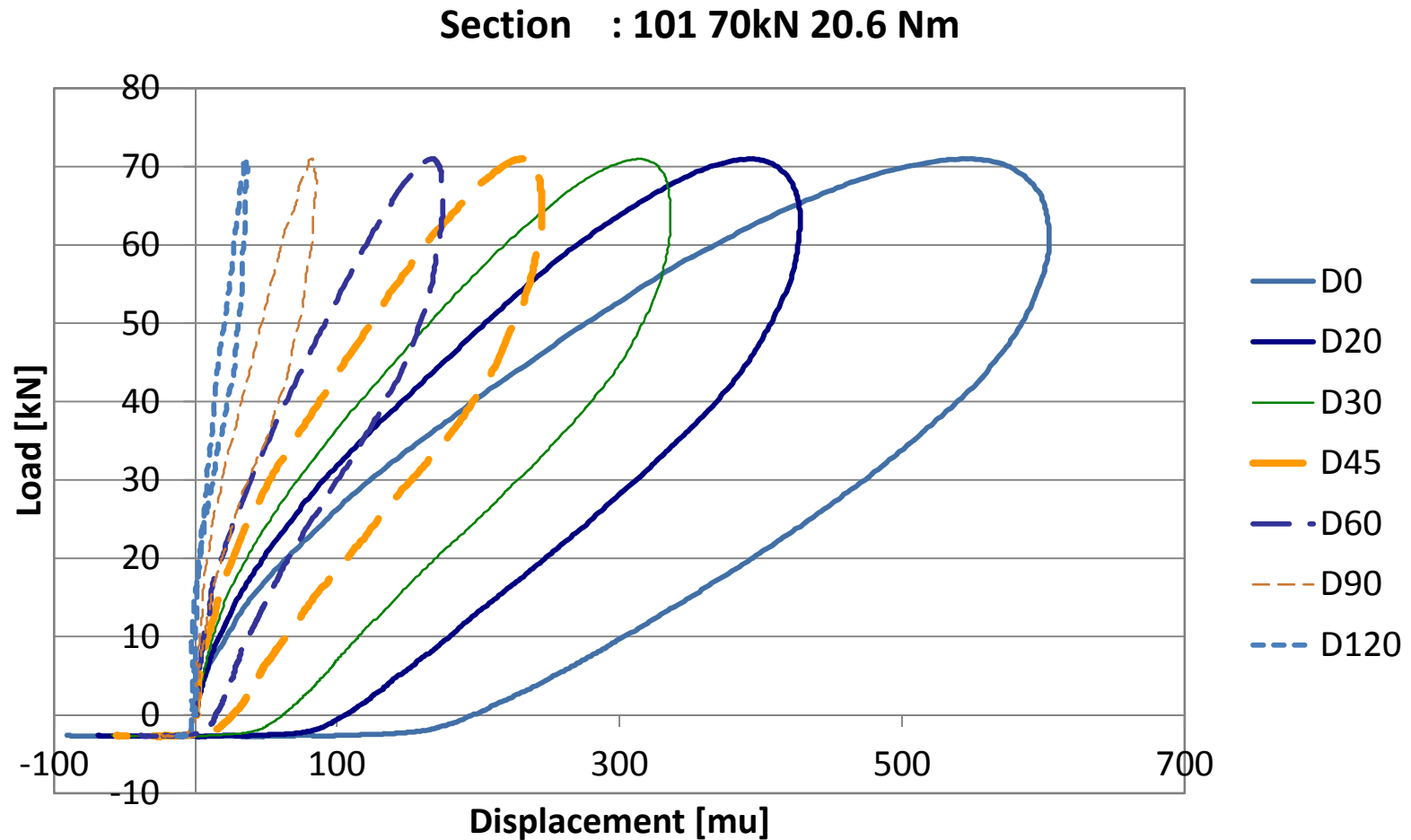
Certainly a drop of layer stiffness over settlement.

Difficult to assess reason, due to a combination of elastic and permanent deformations

Visby Load-Deflection diagram



Visby Load-Deflection diagram



Conclusions

- Time histories reveal that the unbound layers are poorly compacted, and that traffic will likely push more material away downward.
- The deficiency is limited to a circle of about two meters (7 ft).
- Surface profiling does not show any other sink holes.
- A full coverage of the runway with FWD testing is recommended.

Conclusions

- If pavements are monitored by FWD
- Time histories reveal:
 - Water present
 - Poor compaction due to sink holes or other reasons.



Conclusions

- Sampling Time Histories does not require more time in the field!



Thank You!
Questions?

